Real Time Driver Information for Congestion Management

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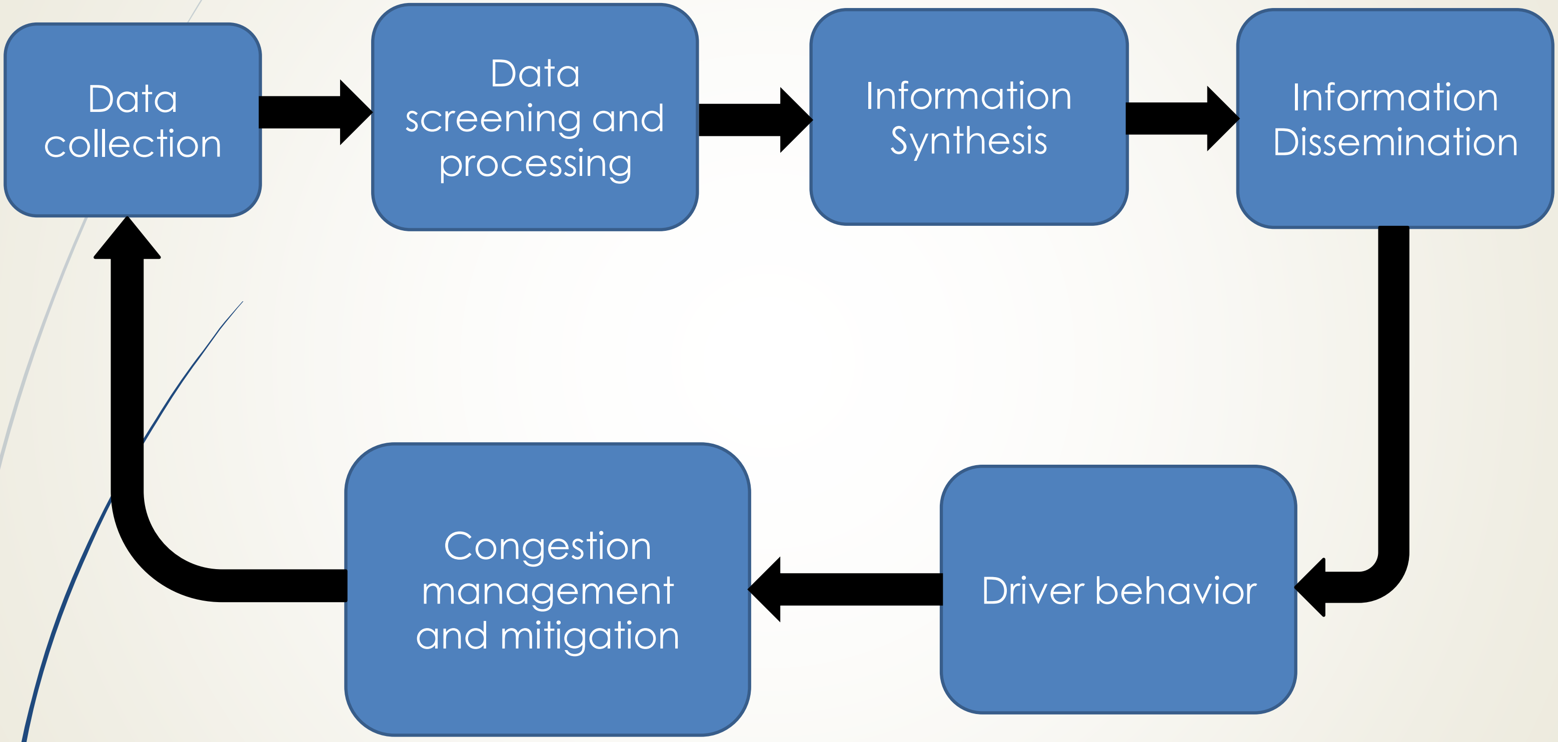
Outline

- Introduction
- Objectives
- Methodology
  - Data Collection
  - Data Screening/Information Synthesis
  - Real Time Information Dissemination
  - Driver Behavior and Active Traffic Management Strategies
- Case Studies
- Conclusions and Recommendations

Introduction and Objectives

- Problem: Traffic Congestion
- Conventional Solution: Build our way out of congestion – costly and ineffective!
- Alternative Solution: Active Traffic Management Strategies
- Focus: Real Time Traffic Information
- Impact: Congestion mitigation via Driver's decision making process at pre-trip planning and en route
- Objectives:
  - Conduct a literature review on past and current research efforts on data collection methods and technologies, data screening and information synthesis, information dissemination, impact on driver's behavior, and active traffic management strategies
  - Review selected case studies

Real Time Traffic Information



STEP 1: DATA COLLECTION

Definition

- Backbone of real-time traffic information system
- Functionality (point sensors, point-to-point, and area-wide sensors)
  - Point sensors (fixed sensors)
  - Point-to-point (detect vehicles at multiple locations or floating car data)
  - Area-wide sensors (fleet of probe vehicles)

Data Collection Technologies/Methods

- Manual counts:
  - Dependent on traffic data observer
  - Traffic data accuracy may not be acceptable
- Pneumatic Tubes:
  - Rubber tubes placed across the road
  - Detects vehicles based on pressure changes
  - Simple but limited lane coverage
  - Efficiency is highly dependent on the weather, temperature, and traffic conditions
- Piezoelectric sensors:
  - Placed in a groove made along the road surface of the lane(s) of interest
  - Volumes, speed, classification and weigh-in-motion

Data Collection Technologies/Methods

- Magnetic loops (Inductive Loops):
  - Conventional, intrusive, weather resistant, high maintenance, short lifetime
  - Vehicle counts, lane occupancy, and speed
- Passive and active infra-red:
  - Non-intrusive, but not weather resistant and no good lane coverage
  - Vehicle counts, classification and speeds
- Magneto-Meters (Passive Magnetic Sensors):
  - Intrusive, not accurate when vehicles follow too closely
  - Traffic counts, speeds, and vehicle classification

Data Collection Technologies/Methods

- Microwave Radar Detector:
  - Non-intrusive, weather resistant
  - Vehicle counts, speeds, and simplified vehicle classification
  - Frequency modulated type (Detects stopped vehicles- Unlimited lane coverage)
  - Continuous wave type (Does not detect stopped vehicles- Limited lane coverage)
- Ultrasonic and Passive Acoustic:
  - Non-intrusive, sensitive to temperature and weather conditions
  - Vehicle counts, speeds, and vehicle classification

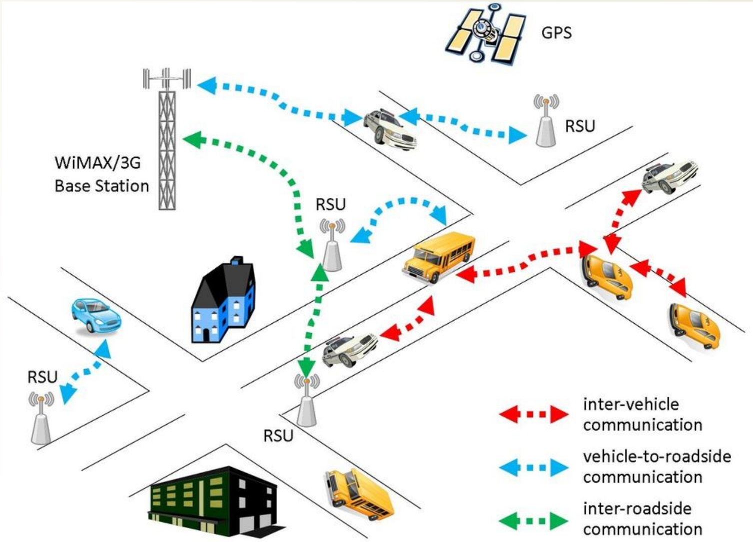
Data Collection Technologies/Methods

- Video Image Detection:
  - Non-intrusive, not weather resistant
  - Vehicle counts, classification, and speed
- Floating Car Data (FCD):
  - Vehicles are equipped with a mobile phone or GPS
  - Vehicle coordinates, travel time, speed, direction of travel (section measurement data)
  - Accurate information on traffic conditions
  - GPS-based, Cellular-based, Automatic Vehicle Identification (AVI)

Data Collection Technologies/Methods

- Bluetooth Technology
  - Non-intrusive, cost effective, weather resistant, reliable
  - Media access control (MAC) address for tracking vehicles and Travel time data
- Emerging Technologies
  - Autonomous vehicles technologies: driverless cars
  - V2V and V2I Technologies: Wireless communication between vehicles and roadside units
  - Traffic speed, traffic conditions, OD flows, route choice, incident locations, and many other data types

V2V and V2I

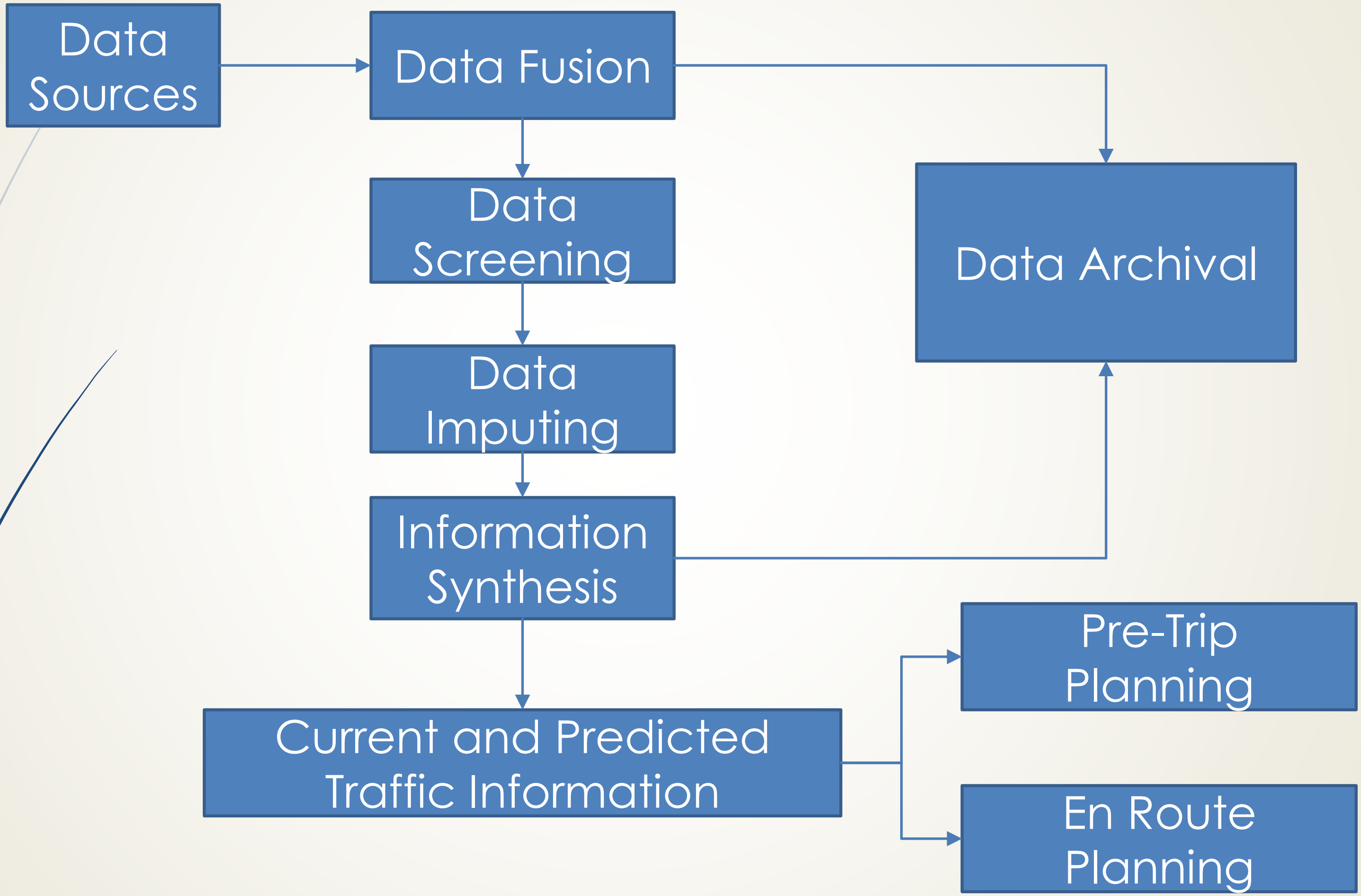


- Equipped with wireless devices
- DSRC (Seven channels-5.9GHZ band-3000ft)
- RSU
- V2V and V2I
- Vehicle Ad-hoc Network (VANET)

Data Collection Method	Intrusiveness	Weather Resistance	Data Collected				Mounting Location	Main drawbacks
			Traffic Counts	Speeds	Classification	Other		
Manual Counts	No	-	Yes	Yes	Yes	-	roadside observer	- Depends on human factors
Pneumatic Tubes	Yes	No	Yes	Yes	No	-	across the road	- Accuracy depends on weather - Limited lane coverage
Piezoelectric Sensors	Yes	No	Yes	Yes	Yes	Weigh in motion	Grooves along road surface of the lane of interest	- Limited lane coverage
Magnetic Loops	Yes	Yes	Yes	Yes	Yes	-	Embedded in the road surface	- Short lifetime
Passive and Active Infra-red	No	Yes	No	Yes	Yes	-	Lane of interest	- Does not work properly in bad weather - Limited lane coverage
Magneto-Meters	Yes	Yes	Yes	Yes	Yes	-	In holes in the pavement	- Not able to differentiate between two vehicles following too closely.
Microwave Radar Detectors	No	Yes	Yes	Yes	Yes	-	At high point on the road	- Some types are not able to detect stopped vehicles
Ultrasonic and Passive Acoustic Devices	No	No	Yes	Yes	Yes	-	Over the lanes of interest or roadside	- Sensitive to temperature and weather condition
Video Image Detection	No	No	Yes	Yes	Yes	-	At high level on the road side or at intersections	- Affected by weather conditions
Floating Car Data	No	Depends on the used GPS and cell phones	Yes	Yes	Yes	Vehicle coordinates and routes information	In Vehicles (GPS or Cell phones)	- Some care may not have GPS or cell phones
Bluetooth Technology	No	Depends on the in-vehicle Bluetooth device	Yes	Yes	No	Travel times	Roadside and in-vehicle Bluetooth devices	- Sensitive to weather
Connected vehicle Technologies	No	Depends on the used devices	Yes	Yes	Yes	Vehicle coordinates, travel times, route information, … etc	In-vehicle and RSU	- Low market penetration at first implementation

STEP 2: DATA PROCESSING

Definition


Data Sources
Data Fusion
Data Screening
Data Imputing
Information Synthesis
Data Archival
Current and Predicted Traffic Information
Pre-Trip Planning
En Route Planning

Data Processing

- Data summarization
  - Descriptive statistics (central tendency and dispersion)
- Data cleaning
  - Data errors: detection of errors and outliers
  - Missing data: data imputing with interpolation-based methods and simple linear regression method from recent and historical data
- Data reduction
  - Multiple data sources-large data sets- difficulty to process (Minimized)
  - Two levels data reduction approach (at acquisition level and at data fusion level)

STEP 3: INFORMATION DISSEMINATION

Definitions

- Distribution of extracted information to road user to influence driver decisions
- Information includes:
  - Travel times
  - Speeds
  - Delay
  - Congestion
  - Bottlenecks queues and
  - Incidents downstream
- Various technologies are used by state DOTs

Highway Advisory Radio

- Information is distributed via broadcast radio
- Traffic delays, emergency operations and construction updates, … etc
- Can reach many travelers at any given time (within the broadcast range)
- Drawbacks:
  - Low power and poor signal quality (AM broadcast band) normally due to weather
  - Requires drivers to take action (turn on the radio to the appropriate station)

Dynamic Message Signs (DMS)

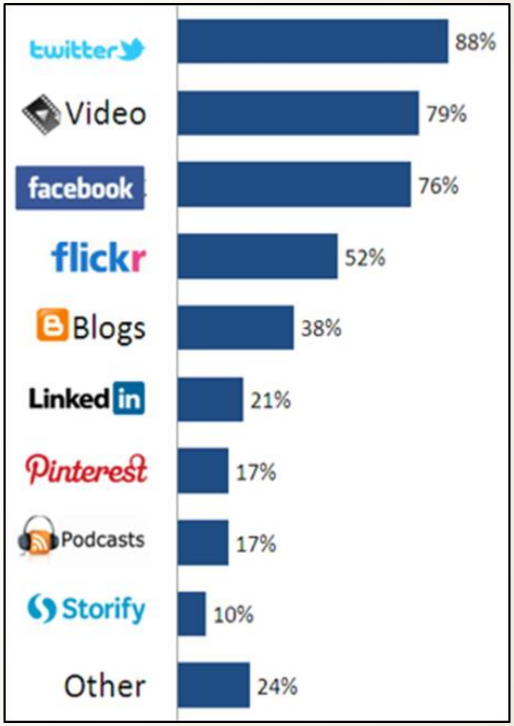
- Also known as CMS and VMS
- Can be programmed to display any combination of characters
- Flexibility to be either permanently fixed or portable devices
- Effective message on a DMS must have five elements: Problem, Location, Effect, Attention, Action
- Incident warning, slow-downs, upcoming speed changes, road work, alternative routes, etc
- Must be able to be read at least twice while traveling at the posted speed limit (MUTCD)

Telephone Information Services (511)

- "511" currently stands as the U.S. official traveler information telephone number
- Pre-recorded messages telling highway conditions, transit agencies and other travel information
- Operated by state and local transportation agencies
- 39 states actively use 511

Social Media

- Most drivers have access to the social networks via smartphones' applications (Twitter, WAZE, INRIX, Way to Geaux, Beat the Traffic)
- Smartphones are used to inform public of roadway incidents in real-time
- Few studies examined how social media influences behavior



Usage percentages of 41 states and Washington, DC

REAL TIME INFORMATION AND DRIVERS' BEHAVIOR

Impact of Real time information on drivers' behavior

- Drivers react to information in terms of route choice, trip time choice, travel speed, etc.
- One study showed that drivers receiving information with smartphones reacted to daily variation in travel times
- Another study showed the effectiveness of DMS in terms of speed reduction and crash rate reduction
- Some studies indicated that in-vehicle traffic information could be distracting due to information overload; other studies showed otherwise
- Several studies showed that real-time traffic information improves the overall performance of the road network.

ACTIVE TRAFFIC MANAGEMENT STRATEGIES

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Dynamic Lane Use (Shoulder Control)

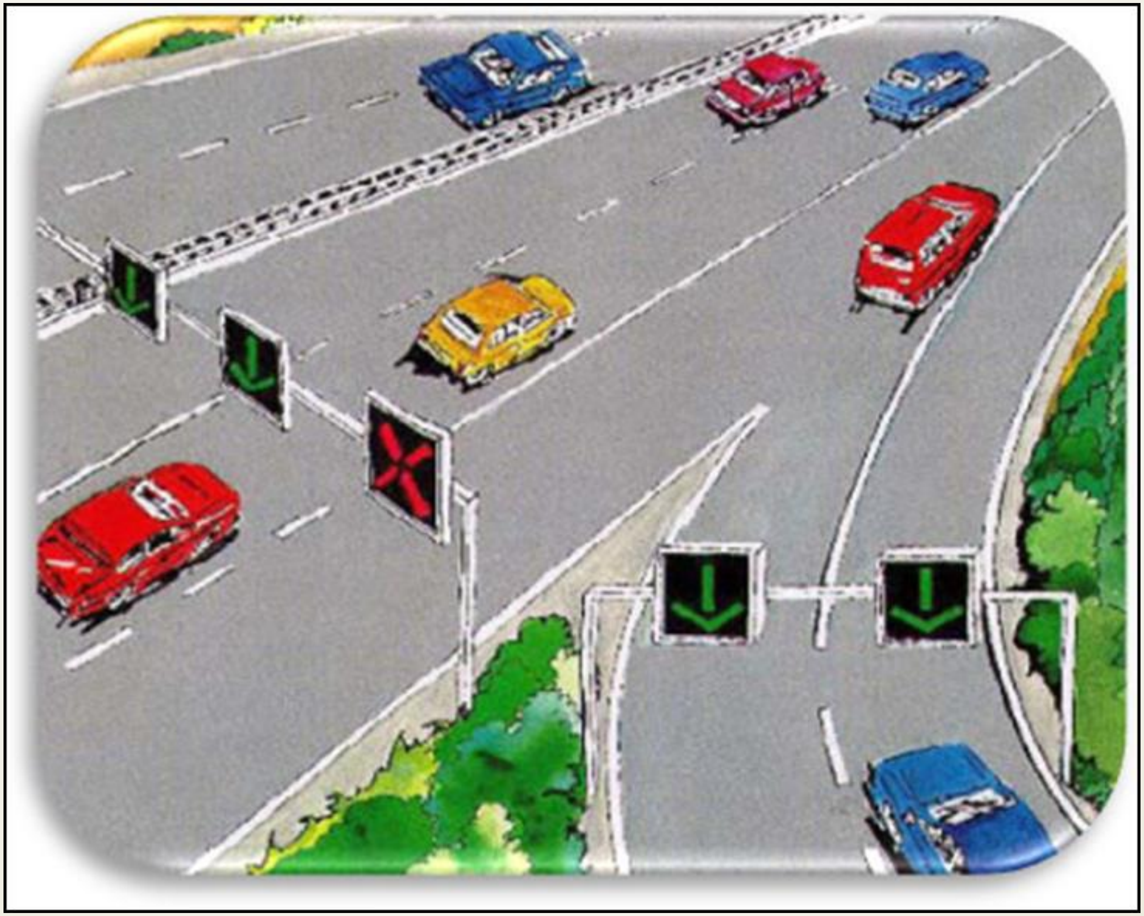
- Dynamic opening of a shoulder lane to traffic or dynamic closure of travel lanes temporarily
- Ideal for congested and high transit volume freeways
- Shoulder running is based on traffic volume, travel speeds, incident presence
- Complementary ATM: variable speed limit, queue warning signs
- Benefits:
  - Postponed onset of congestion
  - Increased capacity
  - Improved trip reliability and travel times
- Challenges:
  - Informing the public when shoulder running is allowed
  - Possible bottlenecks at the end of the open shoulder segment

Dynamic Lane Use (Shoulder Control)

Dynamic Merge (Junction Control)

- Adjustment or closure of a lane or lanes upstream of an interchange.
- Ideal for congested freeway with high merging volumes
- Benefits:
  - Delayed onset of congestion
  - Increased capacity
  - Improvement of traffic efficiency and reliability
- Challenges:
  - Gaining public support
  - Design and operations of the junction control area
- Data necessary: Maximum capacity of upstream lanes, Traffic volumes on general purpose lanes and merging ramps, Travel speeds, Incident presence and location

Dynamic Merge (Junction Control)



Variable Speed Limits

- Changeable signs that reduce the speed limit in 5 mph increments downstream
- Ideal for congested freeways and areas prone to adverse weather
- Roadway or weather sensors are used with variable speed limits
- Benefits:
  - Improved traffic flow
  - Uniform traffic slowing or speed harmonization
- Few challenges with public support and operations of variable speed limits
- Enforcement issues
- Data required: Traffic volumes, Travel speeds, Local climate and weather conditions, Incident presence and location

Variable Speed Limits

Queue Warning and Dynamic Message Signs (DMS)

- Queue warning signs alert drivers of queues or backups downstream
- Loop detectors are used to help identify possible queues backing up
- Benefits:
  - Reduced congestion
  - Reduction of rear-end crashes and improved driver safety
- Challenges:
  - Data quality and reliability
  - Determining appropriate location for sensors
  - Public awareness
  - Operations and management
- Data required: Traffic volumes, Travel speeds, Travel times, Incident presence and locations.

Queue Warning and Dynamic Message Signs (DMS)

Dynamic Route Guidance (DRG)

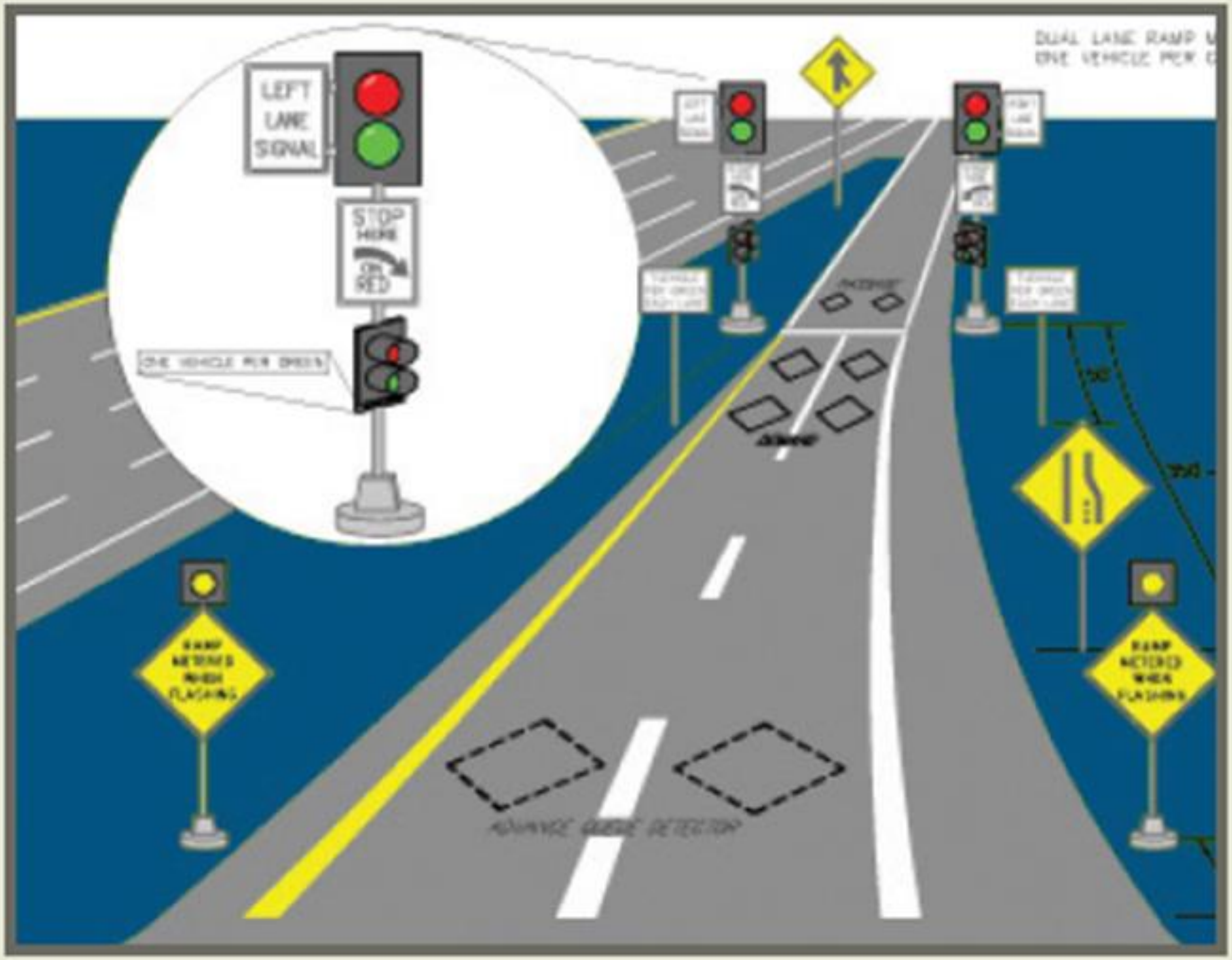
- Develops optimal real-time distribution of traffic
- Different algorithms are used according to congestion levels and real-time traffic conditions
- DMS or in-vehicle systems are used to inform drivers with recommended routes
- Data required: Congestion information, Travel times

Dynamic Route Guidance (DRG)

Adaptive Ramp Metering

- Metering rates are altered according to traffic conditions
- Ideal for freeways with recurring breakdowns, congested metropolitan areas and stop-and-go traffic conditions
- Benefits:
  - Decreased crash rates in controlled areas
  - Increased traffic volumes and speeds
  - Relatively low construction cost
- Challenges:
  - Potential violations
  - Negative public perception of ramp delay to local traffic
- Data required: Traffic volumes, Travel speeds, Ramp demand and geometry, Crash history

Adaptive Ramp Metering



Advanced Arterial Traffic Control (AAC) system

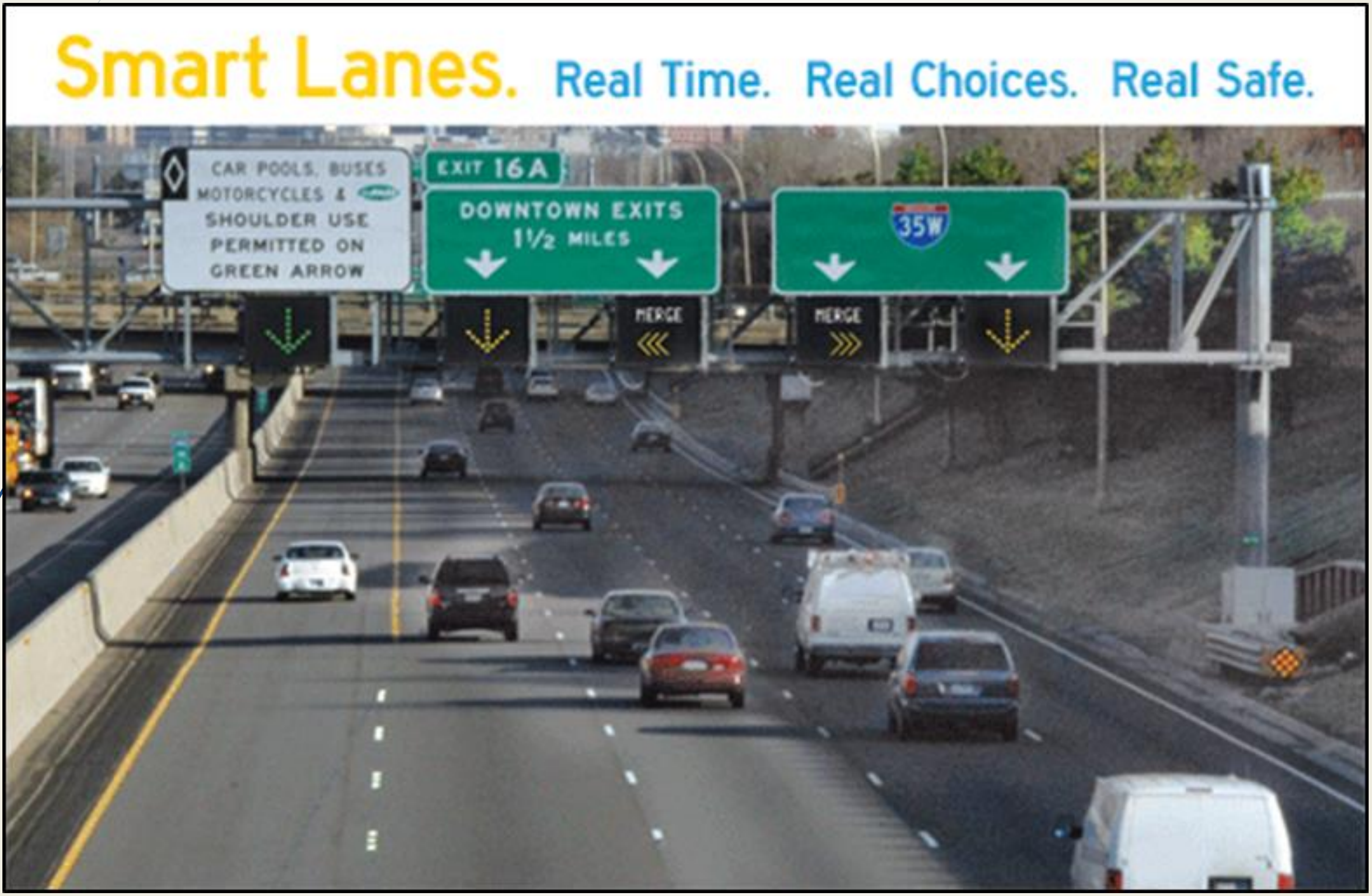
- Managing traffic flow throughout the arterial network including signalized intersections
- Different sensors (e.g. loop detectors) are used
- Signal controllers to continuously adjust signal timing
- Allow a platoon of vehicles to pass through few intersections continuously
- Benefits:
  - Reduce travel time and congestion
  - Improve safety

CASE STUDIES

Smart Lanes: Minnesota DOT

- Dynamic lane use control, dynamic speed limits, queue warning and adaptive ramp metering strategies.
- Green arrows indicate a lane is open.
- Yellow arrows provide warnings to proceed with caution.
- Red X signifies the lane is closed-drivers should begin to merge out of the closed lane.
- 30% reduction in collision and 22% increase in roadway capacity.

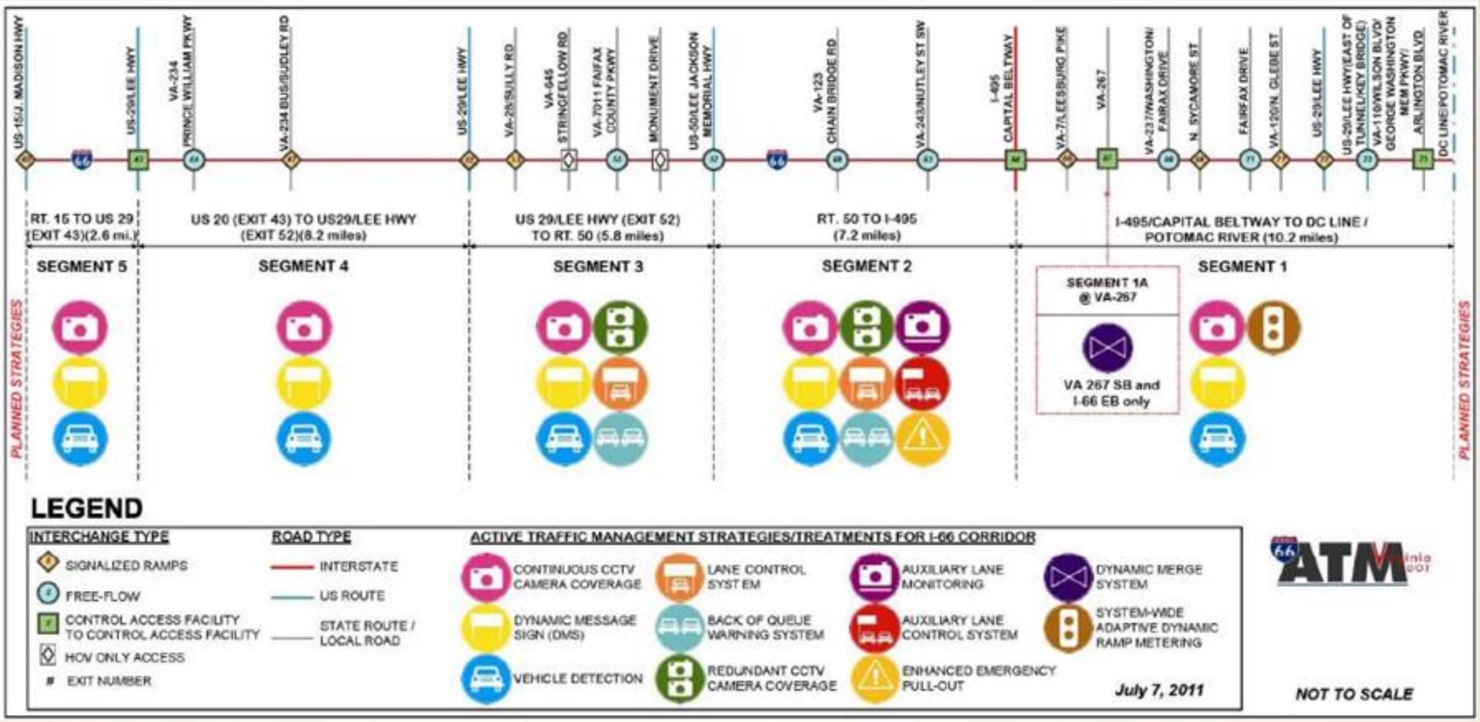
Smart Lanes: Minnesota DOT



Multiple ATM Strategies: Virginia DOT

- A major project dealing with active traffic management on Interstate 66 by 2015.
- 34 miles along I-66 from the District of Columbia to Prince William County
- Multiple active traffic management strategies and technologies.
- Dynamic shoulder use will be allowed.
- DMS and lane control systems to alert drivers.
- Other ATM strategies and technologies will be implemented.

Multiple ATM Strategies: Virginia DOT



Exact project layout and type of ATM strategy utilized in each segment

Variable Speed Limits: Missouri DOT

- Variable speed signs along I-270 and I-255 in St. Louis, MO
- Aided in the reduction of crashes and some congestion
- Enforcement was challenging due to driver confusion
- Variable speed limits were converted into variable advisory speeds
- Yellow and black color stating "Advisory When Flashing"
- Advisory speed range increases from 10mph in extreme congestion, to 60mph during very light traffic
- 10% increase in average throughput, reduction in congestion
- 4.5% to 8% crash reduction
- Upcoming congestion, inclement weather conditions, work zone lane closures or stopped vehicles ahead
- Dynamic Message Signs

Variable Speed Limits: Missouri DOT

MoDOT variable advisory speed sign

Multiple ATM Strategies: Texas DOT (Austin)

- Variable speed limits
  - Harmonized traffic flows, reduced the amount of lane changing conflicts, and provided improved safety on freeways
  - Reduced the likelihood and severity of conflicts
- Shoulder lane use
  - Reduced traffic density and increased operational speed
  - Speed at the end of the shoulder use segment decreased
  - Safety on the corridor was improve
  - Comprehensive evaluation is required
- Ramp Metering Strategy
  - Reduced the average number of stops per vehicle
  - Homogenous speed among vehicles
  - Reduced corridor delay
  - Overall network delay increased because of vehicles queuing during the peak traffic on ramps

Multiple ATM Strategies: Texas DOT (Houston)

- Queue warning system
  - Combat the a bottleneck issue at an interchange.
  - Before and after analysis throughout 2008 and early 2009.
  - Higher average speeds and reduced variance of driver speeds over all lanes.
  - 5% to 7% reduction in rear-end crashes at I-610, while no significant change at US 59.
  - Speed variance reduces.
  - Longer study be conducted.

Conclusions

- No single data collection technology or method can provide accurate widespread coverage of the network under all weather and traffic conditions
- Today's technology is geared more towards point to point measurements rather than point measurements. Travelers are more interested in such information (e.g. travel time, delay, etc.)
- Accurate real time traffic information requires integration of several data sources and advanced data processing tools to remove erroneous data and impute missing data
- Next generation technology for V2V and V2I offers a solution to today's limitations on network coverage at low cost infrastructure, as well as a more efficient and accurate dissemination tool

Conclusions

- The effect of real time information on pre-trip planning and en route decision making is evident but difficult to measure
- Social media is effective in information dissemination and used by 41 states
- DMS is recognized to be the mostly used technology by different TMCs.
- The abundance of data can lead to a wealth of information and subsequently information overload if disseminated to travelers. Travelers should customize the information based on their travel needs

Conclusions

- Short term predictive information is very useful to travelers at the pre-trip planning stage
- As data sources increase, more advanced data mining algorithms are required to deal with big data
- Current active traffic management strategies rely on traffic information relayed to management centers and travelers
- Case studies reviewed show use of multiple strategies at the same time is more effective

Recommendations

- What is the required traffic data accuracy?
- What are the most effective traffic data screening methods to be used?
- What are the most effective ways to disseminate the extracted traffic information to the drivers?
- What is the impact of information on drivers' behavior and the congestion management?
- What Integrated active traffic management strategies can aid in reducing congestion?

THANK YOU!